REPORT DOCUMENTATION PAGE

Form Approved
OMB NO. 0704-0188

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE November 25, 2000	3. REPORT TYPE AND DATES COVERED Final Report 7/1/95 - 12/31/96

4. TITLE AND SUBTITLE
Alexandrite Lidar Receiver

5. FUNDING NUMBERS
DAAH04-95-1-0390

6. AUTHOR(S)
Thomas D. Wilkerson

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Utah State University
Logan, UT 84341

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U. S. Army Research Office
P.O. Box 12211
Research Triangle Park, NC 27709-2211

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
ARO 34726.1-EV-RIP

11. SUPPLEMENTARY NOTES
The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other documentation.

12 a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

12 b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

Utah State University's responsibility to the U.S. Army Research Office and the DoD's DURIP'96 Program was to design, and obtain from a vendor, an "Alexandrite Lidar Receiver". The chosen vendor, Orca Photonics, In. (Redmond, WA), in close collaboration with USU personnel, built a portable, computerized lidar system that not only is suitable as a receiver for a near IR alexandrite laser, but also contains an indenpendent Nd: YAG laser for stand-alone lidar operations at 532nm. The LRS-100 lidar delivered under this contract has two analog PMT receivers channels to detect both in daytime as well as at night. Though zenith observations are the typical operational mode of the Orca lidar, we also demonstrated off-zenith lidar measurements using a mirror beam-director and a holographic transmission grating (HTG) on the receiving telescope. ARO's satisfaction with the Orca lidar has led to funding for a separate USU contract to Orca (now completed under DURIP sponsorship) to add two digital (Photon counting) channels for greater sensitivity and range, particularly for nighttime observations. ORCA Photonics, Inc. has proved to be an excellent, responsive vendor for industry-university collaborations.

14. SUBJECT TERMS
alexandrite lidar, YAG lidar, portable lidar, Orca Photonics, HOLO campaigns, polarization, clouds, aerosols, backscatter.

15. NUMBER OF PAGES
9

16. PRICE CODE

17. SECURITY CLASSIFICATION OR REPORT	18. SECURITY CLASSIFICATION ON THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev.2-89)
Prescribed by ANSI Std. 239-18
298-102

DTIC QUALITY INSPECTED 3

20010116 096

Alexandrite Lidar Receiver

Final Report on US Army Research Office Contract DAAH04-95-1-0390

Thomas D. Wilkerson
Center for Atmospheric and Space Sciences
Utah State University, Logan, UT 84322-4405

Tel.: 435-797-4071
eMail: tdw@sdl.usu.edu

Abstract

Utah State University's responsibility to the U.S Army Research Office and the DoD's DURIP'96 program was to design, and to obtain from a vendor, an "**Alexandrite Lidar Receiver**". The chosen vendor, Orca Photonics, Inc. (Redmond, WA), in close collaboration with USU personnel, built a portable, computerized lidar system that not only is suitable as a receiver for a near IR alexandrite laser, but also contains an independent Nd:YAG laser for stand-alone lidar operations at 532 nm. The LRS-100P lidar delivered under this contract has two analog PMT receiver channels to detect both the direct- and cross-polarized lidar returns, and is capable of cirrus cloud measurements in daytime as well as at night. Though zenith observations are the typical operational mode of the Orca lidar, we also demonstrated off-zenith lidar measurements using a mirror beam-director and a holographic transmission grating (HTG) on the receiving telescope. ARO's satisfaction with the Orca lidar has led to funding for a separate USU contract to Orca (now completed under DURIP sponsorship) to add two digital (photon counting) channels for greater sensitivity and range, particularly for nighttime observations. Orca Photonics, Inc. has proved to be an excellent, responsive vendor for industry-university collaborations.

November 2000

ALEXANDRITE LIDAR RECEIVER

Foreword

This is a replacement of the Final Report on the results of the DURIP support for ARO contract DAAH04-95-1-0390, delivered well after the completion and delivery of the lidar equipment. We believe that a previous report on this contract, including the Orca Photonics brochure and lidar performance data, was submitted to the ARO. However it cannot be found either at USU or ARO, so this follow-up is necessary. Moreover, the passage of time has provided the opportunity to fully test and demonstrate the excellent qualities of the lidar equipment built under the contract. Thus this Final Report actually provides a better basis for evaluating of the results of the investment of ARO's generous support.

Summary of the most important results

USU's issuance of the Orca Photonic Systems contract based on the ARO support has led to a new commercial product in the remote sensing field, plus a follow-on contract (DAAG55-97-1-0068) for the lidar upgrade to greater sensitivity and dynamic range. The resulting lidar system is compact, portable, and is designed to operate safely in a variety of environmental conditions.

The lidar specifications and configuration are described here in Appendix A, which is a copy of Orca's commercial brochure on the LRS 100P (Orca's commercial designation). At Utah State University we designate this lidar by the name AROL, for Army Research Office Lidar.

Through the development of AROL, the support by the Army Research Office has resulted in the production of a transportable, self-contained, and user-friendly system complete with operational and data reduction software. This is a significant addition to the United States' technology base in the field of remote sensing, enabling potential customers to carry out remote observations of the atmosphere without having to develop expensive new systems from scratch. Moreover Orca's first AROL system has been shown to be expandable into greater capabilities, as demonstrated by the augmented sensitivity modifications described in *Wilkerson (2000).* An overall summary of Orca's development program has been given by *Moody et al. (2000).*

In the areas of research and student training, the suitability of the Orca lidar for routine use and for measurement campaigns in the field has been demonstrated in two 1999 test exercises in Utah and New Hampshire, designated HOLO-1 and HOLO-2. Specifically, we have used the original (i.e., pre-augmented) functions of AROL for daytime and nighttime zenith ranging to clouds, at altitudes up to 12 km. Coupled to conventional

video imagery of the daytime clouds, this has made it possible to measure horizontal wind velocity vectors at cloud altitude, such as has been reported by *Pal et al. (1994).* This year three presentations have been given on AROL-related parts of the HOLO observations by *Sanders et al. (2000)*, *Schwemmer et al. (2000)*, and *Wilkerson et al. (2000).*

The integrity of Orca's design and construction of AROL have been well demonstrated in difficult winter weather in Utah during the HOLO-1 campaign (March 1999), and in HOLO-2 (June 1999) when this lidar was shipped overland to New Hampshire and put into operation with virtually no adjustment of the optics. The system is robust and runs with good user-friendly software developed by Orca. The choice of laser for AROL has proved to be very important. The Nd:YAG laser provided by Big Sky, Inc. is very reliable and has had to be adjusted only once by the vendor. The quality of this vendor's service is excellent. Big Sky provided one day turn-around service on the laser when we were preparing to ship AROL for the HOLO-2 campaign.

We refer the reader to the paper by *Moody et al. (2000)* as the most comprehensive published account of the rationale, design, and construction of the AROL lidar initially constructed under ARO contract DAAH04-95-1-0390.

Acknowledgement

While this type of work could, in principle, have been done earlier with the original AROL equipment, there was no good opportunity to do so until we were fortunate to develop a favorable research environment through the facilities and IR&D support by USU's Space Dynamics Laboratory (SDL). This support is ongoing and provides the foundation for other AROL applications, such as the possibility of participation in the DoD's SERDP tests in 2001 and 2002 at Ft. Bliss. We are pleased to acknowledge SDL's contributions that have made it possible to fully exercise the AROL lidar system.

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"Comparison of Two Lidar Methods of Wind Measurement by Cloud Tracking", **J.A. Sanders, T.D. Wilkerson, G.K. Schwemmer, David O. Miller, D.V. Guerra, and S.E. Moody**, *Proc. 20th International Laser Radar Conference*, Vichy, France (July 10–14, 2000).

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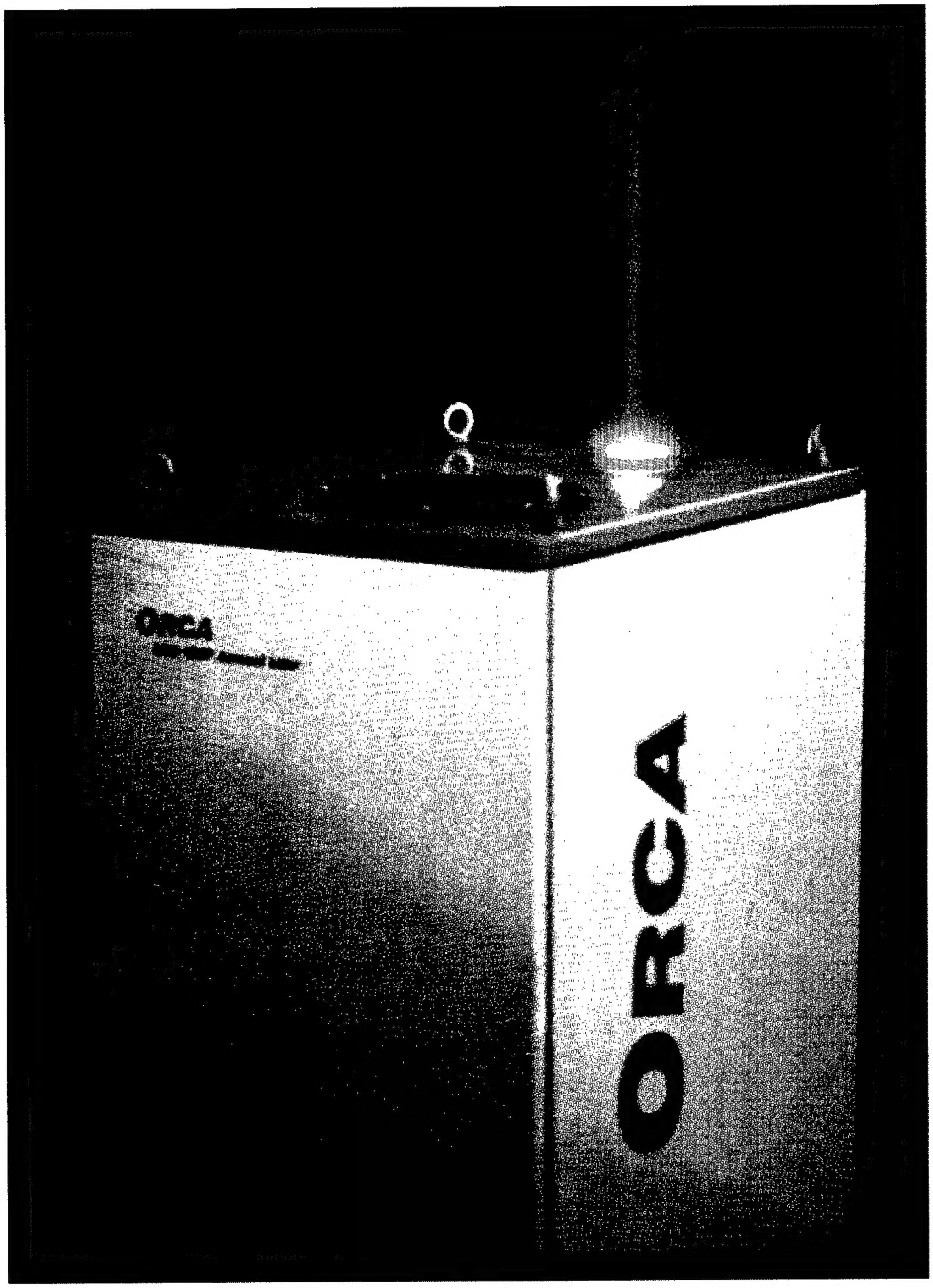
"The HOLO Series: Critical Ground-Based Demonstrations of Holographic Scanning Lidars", **T.D. Wilkerson, J.A. Sanders, I.Q. Andrus, G.K. Schwemmer, D.O. Miller, D.V. Guerra, J. Schnick, and S.E. Moody**, *Proc. 2nd Asia-Pacific Symposium on Remote Sensing*, Sendai, Japan, (October 9–12, 2000); SPIE **4153-09** (7 pp.).

Appendix A

Brochure and specifications for the AROL lidar system built by Orca Photonic Systems, Inc., Redmond, WA

(commercial designation by Orca is LRS 100P)

LRS-100P
Aerosol Lidar



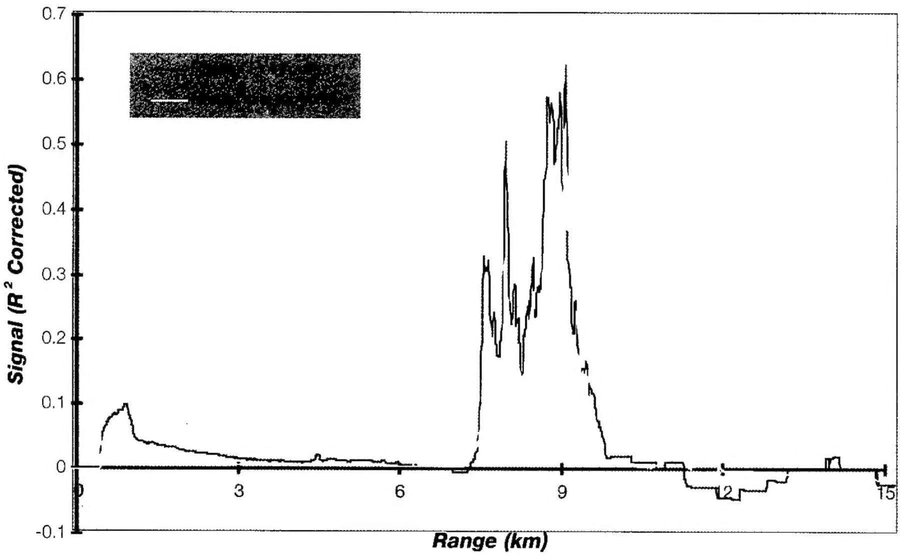


Figure 1. Typical 10-minute integration, showing thin cummulus.

Introduction

The LRS-100 family of backscatter lidar systems provides complete, packaged turnkey capability for the full range of aerosol and particulate measurement applications. This compact and easy-to-use system is custom-configured for each specific application, beginning with a ruggedized Nd:YAG laser transmitter.

Despite its small size and modest price, the LRS-100 offers high measurement capability. Figure 1 shows a typical data acquisition set, taken with a dual-polarization LRS-100 system. Thin cirrus clouds near 10-km altitude are readily visible in this 10-minute run, and the changes in the de-polarization ratio, with range through the cloud layer, show a change in cloud structure with altitude.

System Configuration

The LRS-100 consists of a single lidar package containing a Nd:YAG laser transmitter, an optical receiver, and various support electronics. An external computer workstation is used for system control, data acquistion, storage, and display. A wide variety of options and variants allows the system to be customized for specific applications. Table I summarizes the characteristics of the baseline system.

Table I

Parameter	*Value*	*Notes*
Wavelength	532 nm	
Pulse Energy	100 mJ	Transmitted energy
Pulse Repetition Frequency	20 Hz	
Receiver Aperture	20 cm	<5% obscuration
Transmitter Aperture	5 cm	Nominal
Range Coverage	0.4–20 km	Minimum overlap – maximum practical, zenith viewing
Field-of-View	1–5 mrad	Variable, zenith viewing
Digitizer	20 MHz @12 bits	
Computer Workstation	Pentium, ≥150 MHz	
Operating System	Windows NT	
Lidar Software	***Profile***™	
Electrical Power Requirement	<1500 VA	@ 120 VAC or 220-240 VAC
System Dimensions	0.8x0.6x2 m^3	Excluding computer
Safety Classification	Class 4	Laser system

Transmitter

The baseline LRS-100 begins with a ruggedized, 100-mJ, 20-Hz frequency-doubled Nd:YAG transmitter. The frequency doubler is integral to the laser head, and the entire assembly is hermetically sealed for maximum protection and reliability. A Galilean beam expander controls the output beam divergence, and lowers the transmitter power density. Precision boresight pointing adjustments are brought out through the transmitter case, so that adjustment can be made without opening the unit.

Receiver

The receiver is a fast, compact Newtonian optical system. The baseline 532-nm receiver uses photomultiplier detectors, which provide a good compromise between sensitivity, dynamic range, and cost. The photomultiplier is actively gated to eliminate overload from solar background, and to prevent saturation by short range returns when seeking maximum system sensitivity. Programmable low-noise high-voltage power supplies are provided for each photomultiplier.The entire receiver is modular, and other detector types and other receiver configurations can easily be installed.

Development of the first LRS-100P system was carried out under a contract from Utah State University (T.D. Wilkerson, P.I.), supported by an equipment grant from the U.S. Army Research Office.

Data Acquisition and Control

The data acquisition subsystem is based on a Pentium workstation running Microsoft's Windows NT operating system. Data acquisition is via a high-speed transient digitizer card that is housed in the workstation. Control, data acquisition, and display are under control of Orca's Profile™ lidar software platform.

Table II

Capability	*Standard*	*Available Options*	*Note*
Packaging	Unitized, rack-mount	- Weather-protected environmental enclosure	Active climate control also available
Polarization Detection	Single linear polarization	- Dual-polarization	
Wavelength	532 nm	- 1064 nm - 355 nm - 1057 nm	
Digitizer Rate	20 MHz @12 bits	- 60 MHz @12 bits - 5 MHz @12 bits	Single channel rate, divide by 2 for dual polarization
Scanner	None, zenith viewing	- 1 mirror, limited elevation range - 2 mirror, hemispherical coverage	

System Options

Pre-configured options are available for system packaging, for wavelength, for dual-polarization detection, and for digitizer capability. Table II summarizes some of the possibilties.

Two major packaging options are available. The lowest-cost option is based on a standard half-height electronic rack, with the lidar optical head located above. As an alternative, the entire lidar can be housed in a weather resistant environmental enclosure, as shown in Figure 2. This housing is suitable for operation in minimally protected outdoor installations. Autonomous heating and cooling can be added if needed.

Beyond these standard options, Orca welcomes your special requirements. We pride ourselves on our ability to deliver custom configurations and capabilities with reasonable pricing and delivery.

Pricing

Please consult the separate price list for the base LRS-100 and options. As a practical matter, lidar systems are largely customized to each specific application. We encourage you to consult Orca for a configuration that will meet your application requirements.

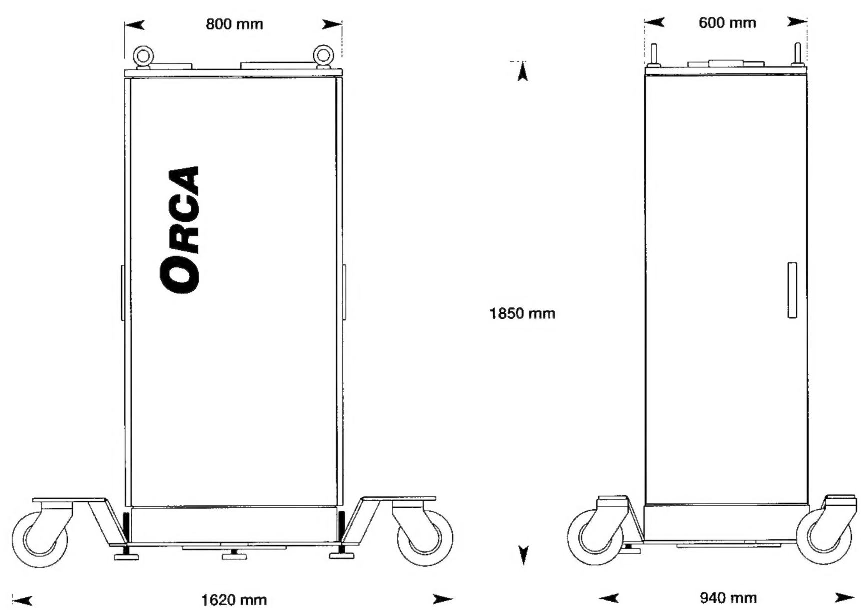
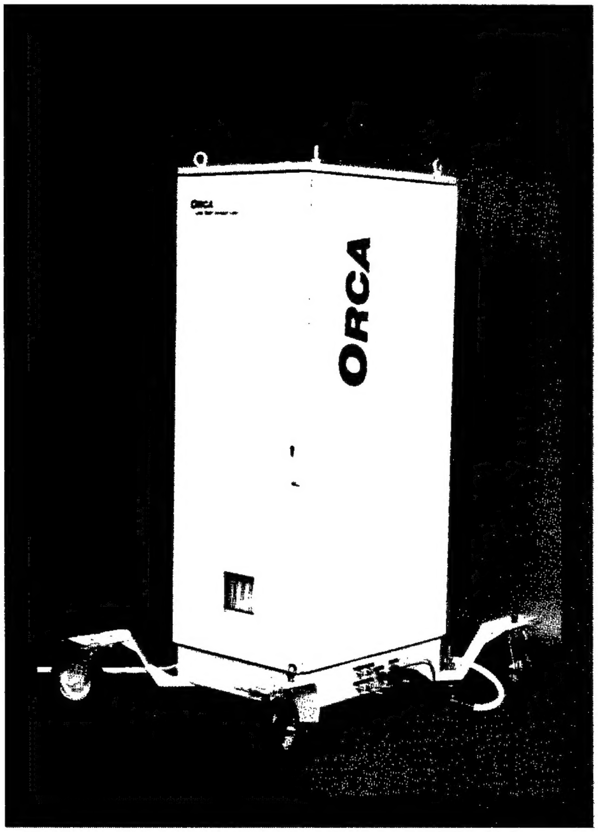


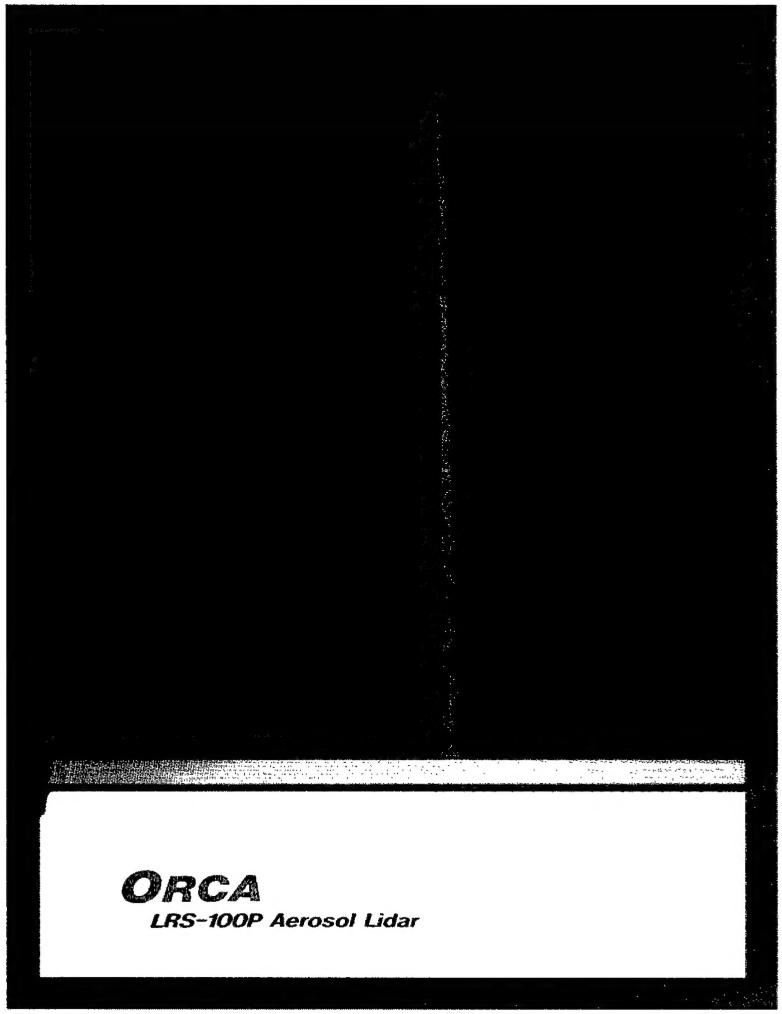
Figure 2. LRS-100 Lidar in environmental housing. The data acquisition computer is separate. The enclosure is a NEMA-12 rated industrial housing.

A Word About the Photographs- The photos in this brochure are the work of Michael Walmsley Photography. The two nighttime shots, which show the system in operation, deserve special mention. Despite their unusual appearance, these shots were not "digitially manufactured", but are accurate photographs of the system while actually operating (and acquiring data). All were taken on traditional silver materials, and then digitally post-processed for adjustment of brightness and dynamic range, but otherwise unmanipulated.



ORCA

Photonic Systems



14683 NE 95th Street • Redmond, WA 98052 U.S.A.
Telephone: (206)702-8706 • Facsimile: (206)702-8806